SCRIPTURE (E.W.)

PSYCHOLOGICAL NOTES.

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COMPLIMENTS
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INDEX
MEDICUS

PSYCHOLOGICAL NOTES.

By E. W. Scripture.

The Method of Regular Variation.

The method of minimum variation seeks to determine that change in the stimulus which produces a minimum change in the sensation. For this purpose the stimulus is varied in one of its properties till the variation is noticed. This is what the usual statement of the principle amounts to when we enlarge it from the exclusive application to the intensity of the stimulus. In applying this method to psychological questions it has up to the present day been changed in such a way that it can scarce be brought into agreement with the above view of it.

Given a stimulus possessing several properties x, y, z. Let one of these properties be varied, e. g. x, while the others are kept constant. We have thus two independent variables x and t, the varied property and the time. The problem is to find for what values of x and t the change becomes noticeable.

The expression for the variation of x is $\frac{dx}{dt}$. Now, if for $t = 0$,

$$v = x_0$$

and in general

$$\frac{dx}{dt} = u$$

where x_0 is a given constant (in this case the value of that property of the stimulus which is to be varied, or the "starting value"), and u is a given function of t, then x is determined for every value of t and the problem becomes: for a given value of the property x, which is varied at the rate u, to determine at what value of x the variation becomes perceptible. The value of x thus obtained is called the *least perceptible variation.*

The variation is likewise completely determined when for $t = 0$

$$x = x_0$$

$$\frac{dx}{dt} = u_0$$

and in general

$$\frac{d^2x}{dt^2} = U$$

where the quantities with the index $_0$ are given constants.

The quantity U as thus defined is called the acceleration of the variation. The value of x corresponding to the least perceptible change can be called *the least perceptible accelerated variation.*

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In applying this method the property x is varied at the rate u, first increasing and then decreasing. This will give two values for the least perceptible variation, D_0 and D_u, from which we take

$$D = \frac{D_0 + D_u}{2} \text{ or } D = \sqrt{D_0 D_u}$$

The quantity D, however, is not a constant but a function of the rate of variation.

To find the least perceptible accelerated variation the intensity is varied, but at an accelerated (or retarded) rate. The results are treated in an analogous manner, and, denoting this quantity by A, we have

$$A = \frac{A_0 + A_u}{2} \text{ or } A = \sqrt{A_0 A_u}$$

A is a function of the acceleration U.

The starting value of x may, however, take on different values, x_0', x_0'', x_0''', ... Consequently the least perceptible variation and the least perceptible accelerated variation are not only functions of the rate of variation and acceleration but also of the starting value; thus,

$$D = f\,(u, x_0)$$

and

$$A = f\,(U, x_0).$$

Up to this point we have taken into consideration only one of the variable properties of the stimulus. In case it has more than one variable property, e. g., y, z, ... the least perceptible variation and acceleration of the property x may, through influences on the attention, etc., be dependent on the values of y, z, . . . If we distinguish the least perceptible variation and the least perceptible accelerated variation of the property x by the index $_x$, then

$$D_x = f\,(u, x_0, y, z, \ldots .)$$
$$A_x = f\,(U, x_0, y, z, \ldots .)$$

Of course the least perceptible variations of y, z, ... are likewise

$$D_y = f\,(u, y_0, x, z, \ldots .)$$
$$D_z = f\,(u, z_0, x, y, \ldots .)$$
$$\cdot \quad \cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot$$
$$\cdot \quad \cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot$$

and the least perceptible accelerated variations are

$$A_y = f\,(U, y_0, x, z, \ldots .)$$
$$A_z = f\,(U, z_0, x, y, \ldots .)$$
$$\cdot \quad \cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot$$
$$\cdot \quad \cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot$$

If, with Wundt, we distinguish the minimum variation from the least perceptible variation, we get slightly different values for D_0, D_u, A_0 and A_u (see Wundt, Phys. Psy. I 350, Leipzig, 1887); in this case the term "minimum variation" and "minimum acceleration" are to be substituted for "least perceptible variation," etc.

In the applications of the method of minimum variation up to the present these quantities have been either neglected or treated in a manner not at all consistent with the method. The usual method or application can be illustrated as follows: Given the stimulus with the variable properties x, y, z, ... to find the least perceptible variation. One of the properties, x, is taken as variable, the others are made constants. Let the starting value be x_0. This starting value x_0 is given constant for an instant and then x is reduced to 0. This value of x,—that is, the absence of the stimulus,—is maintained for a time, n seconds; then another value of x is given, e. g. $x_0 + \Delta x_0$ and the person experimented upon is asked whether this value is perceived as different from the starting value of x. If not, x_0 is again given and after the same time, n sec-

onds, another value of x, e. g. $x_0 + \Delta x_0$, is given and the same question is again asked.

This is an entirely different problem from the one proposed for solution. Here we have the question of a judgment of the likeness or difference between two stimuli given at two different times, or between a stimulus $x_0 + \Delta x_0$ and the *memory* of a stimulus x_0 which occurred n seconds before. The fact that we are able to judge with great accuracy this likeness between a stimulus and the memory of a stimulus given a short time before is not to the point; although that problem is one of vital interest also, it is not the same as the problem of the least perceptible variation of the stimulus x.

I have said that the quantities considered above have been neglected in previous investigations. I must, however, make at least one exception, namely, the original and weighty essay of Hall and Motora, *Dermal Sensitiveness to Gradual Pressure Changes*, AM. JOURNAL OF PSYCHOLOGY, 1888 I 72, to a study of which I owe the impulse to a development of the method of regular variation and to its application instead of the old form of the method of minimum variation. This is, as far as my knowledge goes, the first time the method has been applied to psychological questions.

It is my intention to apply this method to a number of the problems of psychology. Two such investigations have already been begun, one on the faintest perceptible sound, the other one on the least perceptible variation of the pitch of tones; some of the qualitative results are given in the following notes. The apparatus in preparation will admit without any change the investigation of the problems of the least perceptible variation of intensity of pitch and of noises, of the lowest perceptible tones with certain (not all) degrees of intensity, and several others of which indications have shown themselves. A slight change will enable the solution of problems concerning the least perceptible accelerated variation; indeed, the difficulty of obtaining a constant rate of variation instead of an acceleration is what first called my attention to the subject of the perception of accelerated variation.

ON THE LEAST PERCEPTIBLE VARIATION OF PITCH.

Continuous variations of pitch are best obtained from the wave-siren. In the wave-siren a constant blast of air is directed against the edge of a rotating disc which is cut into waves so that a variation of the current of air is produced which follows the law

$$y = a \sin \mu t$$

where y is the change in the current at the moment t, a is the extreme value of y and μ is the vibration-index. This gives a simple tone, the pitch of which depends on the rate of rotation.

One of the chief purposes for which the wave-siren has been set up in Clark University is the investigation of the sensitiveness to variations of pitch according to the method of regular variation. The researches of of Delezenne,[1] Seebeck,[2] Preyer[3] and Luft[4] have been made with continually increasing accuracy, but all of them have left out of consideration the important element of time. The influence of this factor is taken into consideration and measured by employing the improved form of the method of minimum variation, namely, the method of regular variation. The arrangements for making the measurements are nearly complete; in the mean time the qualitative result has already shown itself.

1. DELEZENNE, Mémoires sur les valeurs numeriques des notes de la Gamme, Recueil des travaux de la soc. de Lille, 1826–27, p. 4.

2 SEEBECK, Beiträge zur Physiologie des Gehör- u. Gesichtsinnes; C. Ueber die Fähigkeit d. Gehörs, sehr kleine Unterschiede der Tonhöhe zu erkennen, Pogg. Ann., 1846 LXVIII 462.

3 PREYER, Grenzen der Tonwahrnehmung, Jena, 1876.

4 LUFT, Ueber die Unterschiedsempfindlichkeit für Tonhöhen, Philos. Stud., 1888 IV 514.

As was to be expected, the least perceptible variation in the pitch of a simple tone is not only a function of the pitch and the intensity but also of the rate of variation. Given a tone of the pitch n and the intensity I where $I =$ constant, to find the just perceptible Δn when the pitch of the tone is varied at the rate $q = \frac{\Delta_n}{t}$. The preliminary experiments already prove that

$$D \propto \frac{1}{q}$$

That is to say, the least perceptible variation increases as the rate of variation decreases, and *vice versa*.

On the Faintest Perceptible Sound.

By means of a specially constructed audiometer I am able to vary the intensity of any given sound at almost any given rate. While preparing for an extensive series of measurements on the least perceptible sound I came across the following remarkable fact.

The audiometer is arranged so that the sound is heard in a telephone, and its intensity depends on the relative positions of the primary and secondary coils. At one point there is an absolute zero, that is, the plate of the telephone is not set in vibration. As the position of one of the coils is changed a vibration is set up in the plate, the amplitude of which depends on the strength of the current. If we change the position of the coil sufficiently the vibration of the plate and the air become great enough for the ear to perceive a sound. The point at which this happens — that is, the faintest perceptible sound — depends on the sensitiveness of the person tested and on several other factors, one of which has hitherto been left unnoticed, namely, the rate at which the threshhold is approached. The influence of the rate manifests itself in a peculiar manner. If the relative position of the coils is very slowly changed the faintest perceptible sound appears at a certain point where the physical vibration has a certain amplitude, which we can denote by p. Thus, when the amplitude of the vibration has been changed from 0 at the rate of q units per second, then the faintest sound perceived is p. But a change in the rate q, according to which the sound is varied from zero, produces a change in the faintest perceptible sound p, making it p'. That is, a change in the rate at which we pass from an absolute zero to the psychological zero causes a change in the relation between the two.

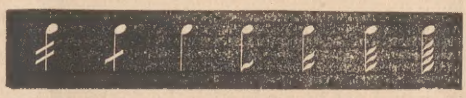
The apparatus for the absolute measurement of sound intensities in units of work has not yet been completed, so I can not give the exact law governing the relation of these quantities; but from the experiments as yet made one fact at least can be determined: the least perceptible sound has a greater physical value as the rate is increased. Judging from rough estimates I should say that this physical value varies as the square of the rate of change.

Notation for Intensity.

Although the modulations of intensity have been carried to a great degree of fineness in music, the amount of intensity in any given case has been left to the semi-conscious judgment of the musician and has not, like the questions of pitch and duration, been reduced to any regularly defined principles. In the history of music the first of the three dimensions of tones to push itself into conscious recognition was that of pitch; thereafter followed duration, and last intensity. The first complete notation for pitch is attributed to Guido Aretius in the XI. century. Three centuries later the notation for duration was introduced by Jean

de Meurs. Naturally the presence of exact means of expression for these two quantities afforded opportunity for development in the artistic execution on the one hand and for scientific research on the other. The subject of pitch has reached a high degree of development. The duration of tones is also a matter of technique that has been carried to a great degree of precision in practice, although it has been scarcely investigated scientifically. The intensity of tones, however, has been much neglected; it must be remembered that we are not speaking of the semi-conscious use of the different degrees of intensity in the execution or composition of a piece of music, but to a deliberate use of the shades of intensity. In music the consideration is confined to the five vague expressions, *ff*, *f*, *m*, *p*, *pp*. In science the question has been treated almost exclusively in relation to the rough tests for deafness. The late attempts to find a measure of the intensity of sound have come more from the efforts of physicists to satisfy the needs of the specialists for ear troubles than from any advance in the music of intensity.

Before much advance can be made, it will be needful to adopt some expressions for the different degrees of intensity to remedy the inconvenience and inaccuracy of the present terms. For the present purposes we can make use of a system limited to ten degrees of intensity. Pitch is indicated by the position of the note on the staff, duration is shown by the hooks on the stems of the notes, except in the case of the whole and half notes, where a difference is made in the head of the note. This change in the head of the note is unnecessary for the indication of duration and can be employed to indicate intensity. A very slight change is thus necessary in the present notation; we can retain the usual method of indicating pitch and the usual signs for duration with the exception of the two for the whole note and the half note. These can be indicated by two lines across the stem of the ordinary quarter note for the whole note and one for the half note. Consequently the series of notes as regards duration will be



representing the whole, half, quarter, eighth, sixteenth, thirty-secondth and sixty-fourth notes respectively.

Whenever it is desired to write music without regard to intensity, it can be done in the same way as at present with the substitution of the two new signs for the whole and the half note, or it can be done as usual without any danger of there being a mistake in the playing of it. Moreover the comprehension and the execution of pieces in the usual style will not be in the least interfered with.

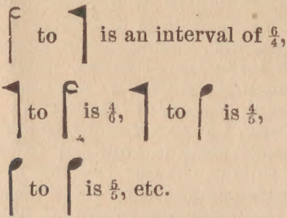
The heads of the notes in the above example are all the same; by employing different kinds of heads the different degrees of intensity can be indicated without introducing new complications in the notation. The degrees can be indicated by a series of new signs. Ten different degrees of intensity are to be represented; they can be said to stand in the relations expressed by the numbers placed under them in following list:

10 9 8 7 6 5 4 3 2 1

These can be used as the heads of notes directly on the staff.

The question arises of how to name intervals of intensity. To avoid the confusion, inaccuracy, and above all the limitedness of the names used for intervals of pitch, we can adopt a simple system in regard to intensity. An interval of intensity is to be designated by a fraction of

which the degree of the denominator is the degree of the first of the two tones, and the numerator that of the second. For example,



All of the degrees used at present can be indicated as well as several more. The worth of the notation does not, however, lie in this, but in the fact that these degrees and distinctions can be introduced into the notes on the staff, thus making it possible to manipulate the shades of intensity in music just as is done with pitch and duration.

A Constant Blast for Acoustical Purposes.

Töpler and Boltzmann in their essay, "*Ueber eine neue optische Methode, die Schwingungen tönender Luftsäulen zu analysiren*," Pogg. Ann., 1870 CXLI 341, make the complaint that it is impossible to obtain a constant pressure of air for blowing acoustical instruments, in spite of the regulators that are applied. They suggest the possibility of using some kind of rotary blower. In making some experiments with organ pipes a while ago, I was forcibly impressed with the same difficulty, although I had access to the best kind of bellows made, namely, that of Cavallé-Col as made by König. At a later date, when contemplating some experiments on the sensitiveness to variation in pitch, I came to the conclusion that unless a far greater degree of constancy in intensity could be obtained, any experiments on the sensitiveness to variation, either in pitch or in intensity, could not be made with the degree of accuracy necessary in psychological experiments. The first step was therefore to find a constant blast. After considerable time spent in fruitless trials I have adopted an arrangement which has proved quite successful.

The chief requisite is a rotary blower giving a sufficient pressure. The blower giving the greatest pressure with the least expenditure of power is the Root direct pressure blower. This, however, is inapplicable for acoustical purposes, owing to the vibrations of the air produced by the cams, which make a deafening noise when the blower is run rapidly. The difficulty is present to a far less degree in the Sturtevant blower. This blower employs a blast wheel of a special pattern, so arranged as to produce a movement of the air from the center to the periphery. Owing to a careful construction of the fans the pressure on blast thus produced has a constancy beyond any means of measurement at my disposal. Moreover, the adjustment of the center of gravity is so good that the wheel can be run at a high speed without danger. There are two disadvantages about the blower, namely, the high speed required to produce sufficient pressure and the production of tones in the blower when going at such a high speed. By courtesy of Prof. Michelson of the physical department of Clark University, I was allowed to run the belt of the blower directly from the drive-wheel of the engine, the drive-wheel being 31 inches in diameter and going at 340 revolutions per minute. The blower used is numbered 0000, stands 12 inches high, has an outlet of $2\frac{1}{2}$ inches, and a pulley of $1\frac{1}{8}$ inch diameter. Driven by this engine the wheel makes 5600 revolutions per minute.

To get away from the noise of the machinery and the tones produced by the blower, a 1½ inch pipe is run to another room, where the sound cannot be heard. The sound brought through the pipe is so faint that it cannot be heard unless the ear is placed at the opening; it thus does not interfere with the use of the blast in any experiments yet tried. A specially made fan with curved blades is said to still further reduce the sound in some blowers lately made. The slightness of the sound produced by the blower is shown by the fact that in running the wave-siren from the lowest pitch up to the highest obtainable, no beats appear, whereas, an attempt to sing the tone of the siren near the rubber tube connecting the mouth-piece with the main pipe at once causes loud beats.

With the wheel running at the above rate and at a distance of 65 feet from the blower, a blast of 10 to 11 centimeters (4 in.) water is obtained. An engine such as here used is, of course, unnecessary. To supply a blast of 12 centimeters pressure with a discharge of 60 cubic feet per minute would require a speed of about 6000 revolutions per minute for the blower wheel and a motor of less than ¼ horse-power. If the motor has a large drive wheel the belt can be run directly from it and no counter-shaft is required.

The great importance of the arrangement here described lies in the greater degree of accuracy thus introduced into psychological experiments on hearing due to the possibility of maintaining a constant intensity.

Some Psychological Terms.

It is the purpose of the present remarks to propose short definitions for a few of the fundamental psychological terms. These definitions are not, however, to be considered as fixed; unchanging definitions are a sign of decrepitude. They ought to progress with the advance of the science; but at each stage of development it is absolutely necessary that certain names should be appropriated to certain things and that everybody should clearly understand just what they are appropriated to.

One of the most abused and indefinite words is "sensation." Bain uses the word to designate the mental impressions resulting from the action of external things on the body. Others take for granted a whole theory of the relation between the mind and the nervous system; Volkmann calls a sensation "the condition which is developed by the soul on the occasion of a nerve-stimulus that is brought to it." Sully defines it as an elementary mental phenomenon that cannot be defined in terms of anything more simple, its meaning being capable of indication only by a reference to the nervous processes on which it is known to depend; as almost absolutely nothing is known concerning these nervous processes, it would seem that the meaning of sensation cannot even be indicated. There is another class of definitions of which this from Carpenter can serve as a specimen: "Sensation is that primary change in the condition of the conscious *ego* which results from some change in the *non-ego* or external world." The easiest way is to shirk the duty of defining the word at all, as only too often occurs. From the lack of acquaintance of the principles of defining which is shown in those that undertake the task, the hesitancy of those who do not is readily understood.

And yet it ought not to be so difficult to agree on some definition. A term is a word used to represent a group of phenomena, a definition is a statement of the phenomena denoted by the term. To avoid the impossibility of going over all the phenomena denoted by the term, we can give a definition by stating what properties a phenomenon must have in order to be denoted by the term, what properties it may not have and

what properties are indifferent. Usually it is sufficient to give the essential properties, omitting the excluding and indifferent ones.

The crying necessity in psychology is a term that shall denote the simplest mental phenomenon, just as "atom" denotes the as yet undivided particles of matter. As such a term we propose the word feeling. Feelings would then be defined as the indivisible elements of mental phenomena; they are as yet unanalyzable components. Nothing is said of the relation to an external or an internal world; no hypothesis is introduced as the nature of mind; all that is assumed are the existence of certain phenomena, called mental phenomena, and the possibility of analyzing them. The ultimate results of the analysis may be what they will, we always have a name for them; with perfection of methods and apparatus the analysis will be pushed further so that what is to-day regarded as a feeling may prove to be a compound, nevertheless the term has always the same meaning.

The proposed definition is by no means entirely new; in fact the word most frequently used to denote simple mental phenomena of all kinds is probably this very term. It is used in almost this way by Spencer. "Each feeling . . . . . is any portion of consciousness which occupies a place sufficiently large to give it a perceivable individuality;" the definition proposed differs from his in not setting apart a special class of "relations between feelings."

Among feelings we find innumerable kinds. When we attempt to class them according to their likeness to one another, we find several ways of arranging them. The most usual way is to class them into two lots, according to whether we regard them as passively experienced or actively experienced. Here is just where we find the thought that is at the bottom of all the array of definitions of sensation; when stripped of theories we can well agree to appropriate "sensation" to the passively experienced feelings. In a like manner "impulse" can be used to designate the actively experienced feelings. These mental elements can, of course, be further classified into sensations of light, of sound, impulses to action, to inhibition, etc.

Terms for the indivisible elements having been obtained, it becomes necessary to have names for the compounds. To designate a psychological compound in general I venture to propose that much abused and at present indefinite word "idea." Possibly this may be justified by referring to an almost similar use of the word by Descartes (See Eucken, Grundbegriffe der Gegenwart, Leipzig, 1878, 225).

Ideas, however, seem to fall naturally into two great classes, according to the preponderance of sensations or impulses in their composition. The former class can be called "percepts" with scarce a departure from such a portion of definite meaning as the name now has. In a corresponding fashion the ideas composed mainly of impulses can be called "volitions." Compounds of higher grades can of course receive appropriate names.

The following list of terms is proposed for psychological use according to the definitions attached to them:

1. FEELINGS are the indivisible elements of which mental phenomena are composed. Every fact of consciousness that has not been proved to be a combination of other facts is to be called a feeling.

2. SENSATIONS are those feelings that are regarded as coming from without; they are passively experienced feelings.

3. IMPULSES are those feelings that are regarded as originated in the mind itself; they are actively experienced feelings.

4. IDEAS are compounds of feelings of any kind; they are the psychical units.

5. PERCEPTS are those ideas that are composed mainly of sensations.

6. VOLITIONS are those ideas that are composed mainly of impulses.